Geospatial Analysis of Urban Heat Island Effects in Dhanbad: A Geographical Study of Sustainable Urban Planning

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CONSENT OF THE SUPERVISOR

I hereby give my consent to supervise the candidate **Nidhi Nalini Ekka** on the proposed synopsis **"Geospatial Analysis of Urban Heat Island Effects in Dhanbad: A Geographical Study of Sustainable Urban Planning"** leading to a Ph.D. degree of the University. I further certify that the synopsis referred to above is to the best of my knowledge and the information has not been published and submitted elsewhere for the award of any diploma or degree.

Date:

Place: Ranchi

Signature of the Supervisor

Geospatial Analysis of Urban Heat Island Effects in Dhanbad: A Geographical Study of Sustainable Urban Planning

1. A BRIEF INTRODUCTION OF THE RESEARCH TOPIC

According to the United Nations World Urbanization Prospects 2018 (UN 2018), it is projected that urban areas will accommodate 60% of the global population by the year 2050. Urban centers serve as pivotal agents of worldwide transformation, marked by a rising influx of inhabitants and substantial pressure exerted on the already limited resources. Consequently, individuals residing in urban environments are increasingly vulnerable to the risk and consequences associated with climate change.

Urbanization has significantly altered the local climates of cities across the world, leading to phenomena like the Urban Heat Island (UHI) effect. UHI refers to the temperature difference between urban areas and their rural surroundings due to human activities and changes in land use. According to Singh.S (2016).[1] The process of urbanization changes the radiation and heat balance at local level which becomes regional in character when the effects are extended to larger areas mainly in big industrial belts. The higher temperature in the CBD (Central Business District) or the city center (knowns 'chowk' in Indian cities) is very often called as urban heat island or simply a heat island.[1]

United state Environmental Protection Agency defines Heat islands are urbanized areas that experience higher temperatures than outlying areas. Structures such as buildings, roads, and other infrastructure absorb and re-emit the sun's heat more than natural landscapes such as forests and water bodies. Urban areas, where these structures are highly concentrated and greenery is limited, become "islands" of higher temperatures relative to outlying areas. Day-time temperatures in urban areas are about 1–7°F higher than temperatures in outlying areas and night-time temperatures are about 2-5°F higher.[2] The 2030 Agenda for Sustainable Development, which encompasses 17 Sustainable Development Goals (SDGs), was introduced to safeguard the environment, foster human prosperity and peace, and rejuvenate international cooperation aimed at sustainable development (Krehbiel et al., 2017). Specifically, SDG 11: Making cities and human settlements inclusive, safe, resilient, and sustainable underscores the critical significance of sustainable urban development (Zhang et al., 2019). The contemporary urban landscape is characterized as a

multifaceted system comprising diverse living elements such as buildings, transportation networks, and aquatic ecosystems. Meanwhile, SDG 13 urges urgent action to combat climate change and its impacts, including adapting urban systems to mitigate temperature rise. Both goals underscore the importance of climate-conscious urban planning to counteract the UHI effect, enhancing live ability and resilience.

Dhanbad, a major coal mining and industrial hub in India, is witnessing urban expansion, leading to increased land surface temperatures and environmental degradation. The rise in construction and decrease in vegetation have led to increased average temperatures, intensify the Urban Heat Island (UHI) phenomenon. This phenomenon results in elevated summer temperatures, with urban regions remaining warmer than adjacent rural areas, particularly at night. The increase UHI effect not only alters the city's climatic patterns but also increases energy consumption, public health issues, and environmental pressures, highlighting the necessity for climate-responsive urban planning consistent with sustainable development objectives. There is a significant gap in integrated research focusing on Dhanbad's Urban Heat Island (UHI) effect. A focused study on Dhanbad's UHI impact is essential to address these gaps and contribute to sustainable urban development and planning while improving the city's resilience to climate-related challenges. This research aims to provide insights for sustainable urban planning and adaptation strategies to the unique challenges faced by similar smaller cities. This study aims to assess the geographical aspects of UHI effects in Dhanbad and explore their implications for sustainable urban planning.

2.STATE OF THE ART

A geospatial study of Urban Heat Island (UHI) effects in Dhanbad highlights that rapid urbanization, industrial activity, and loss of green cover have significantly increased surface temperatures, ranging from 31.5°C to 39.7°C between 2019 and 2022. The sharp drop in temperature during the 2020 COVID-19 lockdown shows how reduced human and industrial activity can lower urban heat. Dhanbad, has experienced swift urbanization driven by mining, industrial endeavors, and an increase in population. This has resulted in major alterations in land use and land cover (LULC), transforming natural surfaces into developed regions. Because of fast urban growth and widespread mining, Dhanbad is an important place to study the Urban Heat Island (UHI) effect.

Peng, S., et al. (2012). highlights the urban heat island effect as a notable indicator of human environmental impact, with varying intensity between day and night due to different influencing factors. This study examines the variations in surface urban heat island intensity (SUHII), which measures the temperature difference between urban and suburban areas, using data from MODIS across 419 global cities. The Vegetation emerges as a critical factor in reducing daytime surface urban heat island intensity (SUHII), underscoring its importance in urban planning as a mitigation measure against urban heat islands.[3]

Nuruzzaman, M. (2015). emphasizes the growing concern of Urban Heat Island (UHI) effects due to urbanization and technological advancements. UHI results from altered land surfaces, poor urban planning, and air pollution, leading to human discomfort and environmental decline. The study examines various methods to mitigate UHI, explaining their mechanisms with illustrations. Key strategies include high albedo materials, enhanced green spaces, strategic planning, permeable pavements, shade trees, and preserving aquatic ecosystems. Notably, green vegetation is highlighted as the most effective solution, though other strategies can also yield substantial benefits. Limitations of each method are also discussed.[4]

MacLachlan,A, et al. (2017). examines how changes in urban land cover contribute to the urban heat island (UHI) effect, focusing on the quickly urbanizing Perth Metropolitan Region (PMR) in Western Australia. Using a multi-sensor approach, it investigates the connection between different land cover types and temperature variations to provide insights for sustainable urban development. This research gives the importance of targeted urban planning policies that consider these temperature impacts to better manage UHI effects and promote sustainable, resilient cities.[5]

Raj, S., Paul, S. K., Chakraborty, A., & Kuttippurath, J. **(2020)**. explains the urban heat island effect, caused by human activities, leads to higher temperatures in cities compared to outskirts, posing health risks and increasing energy consumption. Research on urban heat island intensity in India's major cities shows varying trends across seasons.[6]

Pramanik and Punia (2020). examined how urbanization leads to swift land use and land cover alterations, affecting regional thermal properties and aiding the formation of urban heat islands (UHIs), especially in Delhi. Their research examined the connection between changes in land use/land cover (LULCC) and land surface temperature (LST) at a sub-district scale using Landsat and MODIS data from 2001, 2009, and 2017. Using classification methods and landscape metrics,

results showed that SUHII was significant in North, Northeast, East, and West Delhi, while less pronounced in South and Southwest regions due to the presence of more green spaces. Findings from this study emphasize localized UHI impacts in Delhi.[7]

Kumar. A. and et al. (2023). conduct an examination of the Urban Heat Island (UHI) phenomena in smaller urban centers and associated mitigation approaches, with particular emphasis on the evolving climatic dynamics in Ranchi attributable to urban expansion and ecological degradation. The research employs temporal LANDSAT imagery spanning from 2000 to 2014 to quantify land surface temperature (LST), uncovering a substantial 135% augmentation in developed land areas alongside a reduction in vegetation (−6.8%) and rock outcrops (−44.16%). The findings indicate that LST is significantly elevated in urban locales compared to peri-urban areas, a consequence of the prevalent barren and rocky landscapes. The study advocates for the adoption of nature-based interventions, including afforestation initiatives and the incorporation of green roofing, as strategies to mitigate the escalating LST in urban and peri-urban settings.[8]

Divya, Sharma., Alka, Bharat. (2009). finds that Urban heat islands in Ranchi increase air conditioning demand, elevate air pollution and heat-related illnesses, and alter the local microclimate, intensify temperature and ozone concentration issues.[9]

Mohanta, K., & Sharma, L. K. (2017). investigates the effects of urbanization on the Land Surface Temperature (LST) of Ranchi, Jharkhand, India, with the goal of contributing to sustainable urban development. By analysing satellite images over time, the study assesses how urban expansion has influenced the Urban Heat Island Intensity (UHII) from 1992 to 2013.[10]

Chopra, R., & Singh, T. (2022). studies Rapid urbanization in India improves quality of life but creates Urban Heat Island effect due to uncontrolled growth. Research shows increasing urbanization rate, worsening climate conditions, and importance of mitigation techniques for cities. Collaboration needed for effective solutions.[11]

Jing, Kong., Yongling, Zhao., Jan, Carmeliet., Chengwang, Lei. (2021). highlights that metropolitan region, such as Ranchi, show heightened vulnerability to heatwaves attributable to the phenomenon of urban heat islands, thereby necessitating the implementation of strategically focused mitigation measures to counteract the rapid increase of temperatures and associated health impacts.[12]

The concept of UHI has been widely studied in cities globally, including metropolitan areas like New Delhi, Mumbai, and Bengaluru. Studies have shown that the UHI effect is influenced by factors such as urbanization, population density, transportation networks, and industrial activity. While larger cities have been extensively studied, the effects of urbanization and climate change on developing cities like Dhanbad remain largely unexamined.

3. ABOUT THE STUDY AREA

Dhanbad, known as the "Coal Capital of India," is a major industrial city in Jharkhand. It is located in the mid-eastern part of the state, bordered by Giridih to the north, Bokaro to the west, Purulia (West Bengal) to the south, and Jamtara to the east. The district of Dhanbad was formed in 1956 by separating parts of the former Manbhum district. It covers a total area of approximately 2,074 sq. km and lies between 23°26’00” N -24°01’00” N latitude and 86°10’00” E–86°48’00” E longitude.

Dhanbad has a sub-tropical climate, experiencing hot summers, a monsoon season, and cool winters. Summer temperatures range from 19°C to 40°C, with May being the hottest month, reaching up to 48°C, often accompanied by high humidity. The rainy season lasts from mid-June to September, with an average annual rainfall of around 1,300 mm. Winters, from December to February, are mild, with temperatures ranging between 11°C and 22°C. In October and November, temperatures vary from 16°C to 31°C.

Dhanbad is one of the most industrially developed regions in Jharkhand, primarily due to its rich coal reserves. The district is home to major coal mining operations run by Bharat Coking Coal Limited (BCCL) and Eastern Coalfield Limited (ECL), both under Coal India Limited. Other companies like IISCO and TISCO also extract coal from the region. The district plays a significant role in India’s coal production, making it a key centre for mining and industrial activities.

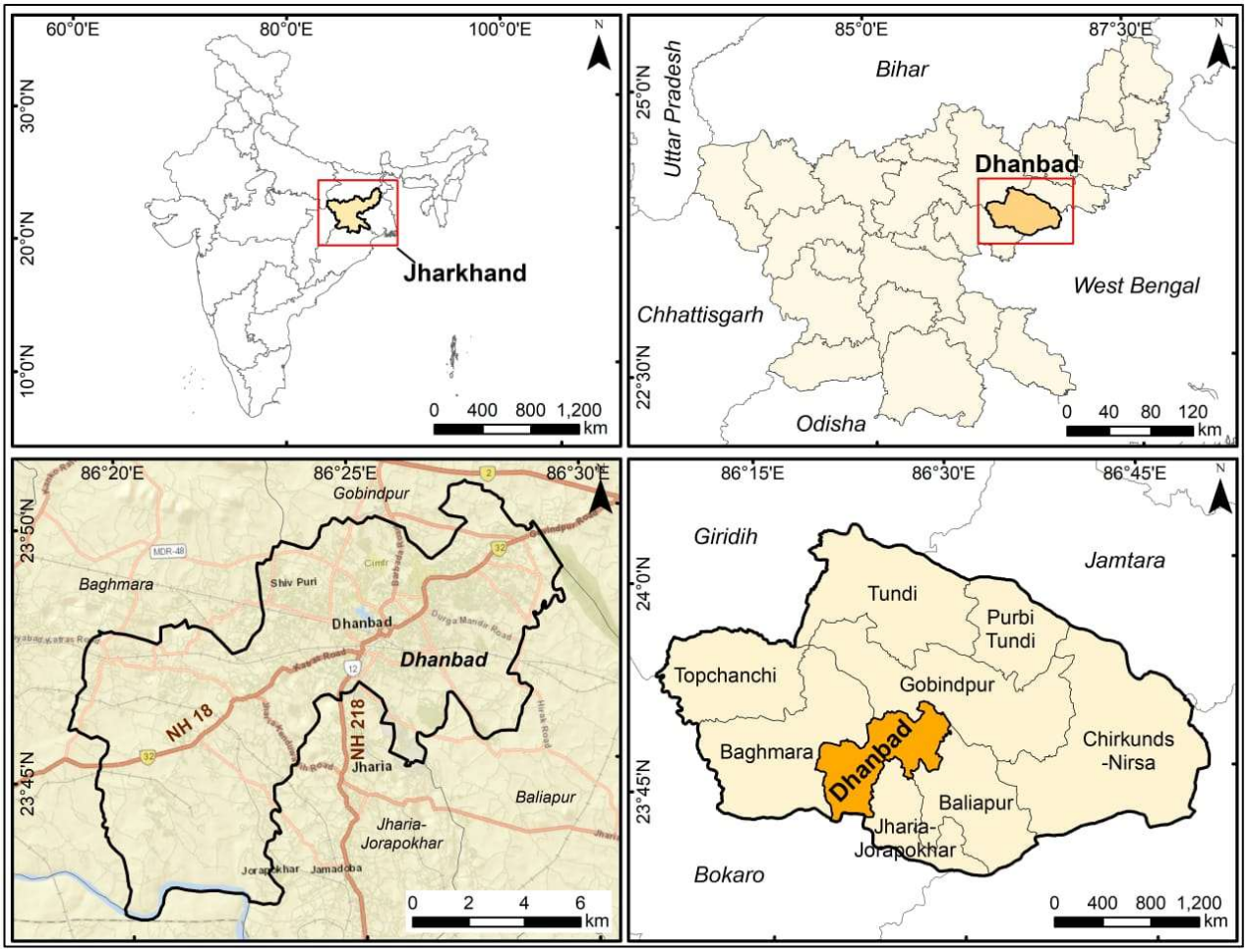

Fig. 1.1 Location map of Study Area

4. PROBLEM TO BE INVESTIGATED

- What are the main factors contributing to the Urban Heat Island (UHI) effect in Dhanbad?
- How has rapid urbanization influenced land use and land cover changes in Dhanbad?
- How does poor urban planning contribute to the intensification of UHI effects in the city?
- What sustainable urban planning strategies can be implemented to mitigate UHI effects?

5.OBJECTIVE OF THE INVESTIGATION AND MOTIVATION

1. To study the spatial and temporal distribution of UHI effects in Dhanbad using geospatial technology.
2. To examine how changes in land use and land cover contribute to UHI formation.

3. To analyse the impact of urban planning practices on UHI effects.
4. To propose sustainable urban planning strategies such as green infrastructure and climate-sensitive designs to mitigate UHI effects.

6. RESEARCH QUESTION AND RESEARCH HYPOTHESIS

- How does urbanization contribute to the Urban Heat Island (UHI) effect in Dhanbad?
- What are the key land use and land cover changes driving the UHI effect in the city?
- What role does urban planning play in intensifying or mitigating UHI effects?
- What sustainable urban planning strategies can be implemented to reduce UHI in Dhanbad?

HYPOTHESIS

1: Rapid urbanization and land use changes have significantly contributed to the Urban Heat Island (UHI) effect in Dhanbad.

2: The intensity and distribution of UHI in Dhanbad are strongly correlated with built-up areas and loss of vegetation.

3: Poor urban planning practices have increased UHI effects, leading to higher energy consumption and health risks.

4: Implementing sustainable urban planning strategies, such as green infrastructure and climate-sensitive designs, can effectively mitigate UHI effects in Dhanbad.

7. RESEARCH DESIGN AND METHODOLOGY

The research design and methodology will provide a structured approach to the entire research is based on Empirical cum Statistical research approach, integrating geospatial analysis, environmental assessment, and socio-economic surveys.

TENTATIVE CHAPTERISATION

Introduction

Chapter 1: Geographical Background of Study Area

Chapter 2: Spatio-Temporal Change in land Use and Land Cover

Chapter 3: Geospatial Analysis of Urban Heat Island

Chapter 4: Urban planning practices and UHI effects

Chapter 5: Sustainable planning and mitigation strategies

Conclusion

- **References**
- **Appendices**
- **Glossary of terms**
- **Bibliography**

8.SOURCES OF DATA AND TOOLS TO BE USED IN COLLECTION OF DATA

Data Sources: 1. The primary data will be based on field observations and ground truthing to find out the accuracy towards the UHI analysis and the sample size of approximately 150, from 10 ward each 15 will be selected for gathering information about the people perception towards UHI.

2.Secondary data

- Toposheet from the survey of India
- Satellite images of national remote sensing agency, Hyderabad
- Landsat data from USGS (United States Geological Survey) earth explorer, MODIS
- DEM from USGS earth explorer
- Resource satellite data from ISRO Bhuvan portal
- Census of India, 2011
- District census handbook of Dhanbad City
- District Vikas Bhawan

The methodology of this study will be based on primary and secondary data, in accordance with its purpose. Primary data will be used in the ground trothing assessment of UHI analysis. UHI analysis is based on Geospatial Data which includes data gathered from satellite imageries and different GIS platforms. With the help of GIS these data will be analyse to measure land surface temperatures and identify UHI hotspots. Stratified random sampling will be conducted to collect the primary data from identified hotspot areas. Secondary data will include Landsat satellite data, IRS-P6, LISS-IV, Survey of India toposheet. Data will used to create the research area's base map as well as thematic maps. Additional computer programs will be used for data processing.

9. ANALYSIS OF DATA

Data Analysis Techniques: The study is widely based on GIS and remote sensing techniques, statistical tools for assessing correlations, and qualitative analysis.

Geospatial Analysis: Remote sensing and GIS techniques will map and quantify UHI intensity across different seasons and neighborhoods.

Public Impact Analysis: Surveys and public health data will provide insights into UHI's effects on residents' health, energy usage, and overall quality of life.

10. SIGNIFICANCE OF THE STUDY

This study will contribute to research by providing new data on the Urban Heat Island (UHI) effect in a mid-sized, rapidly urbanizing city like Dhanbad, which has been mostly underexplored in UHI studies. It will provide valuable insights into how land use changes and urban growth impact local climate patterns. The findings can improve the understanding of UHI effects in smaller cities and the socio-economic conditions of people, complementing research on larger metropolitan areas. Additionally, the study will contribute to developing practical mitigation strategies, which can be applied in other similar cities to address urban heat challenges in the context of climate change and sustainability. The study will contribute to the broader understanding of UHI in mid-sized, developing cities, which have been understated in UHI research.

11.ITS RELEVANCE TO THE PRESENT-DAY PROBLEM AND NEEDS OF THE SOCIETY

With increasing global temperatures and rapid urbanization, cities like Dhanbad are experiencing the Urban Heat Island (UHI) effect, where urban areas become significantly warmer than their surroundings. This study is important as it explores how urbanization affects local climate, energy use, and public health. Rising temperatures increase the demand for cooling, raise electricity costs, and worsen heat-related illnesses, particularly for vulnerable communities. By studying how land use changes influence UHI, this research will suggest sustainable solutions like green infrastructure and better urban design. The findings will help urban planners and policymakers develop climate-responsive strategies to reduce heat impacts, improve living conditions, and ensure sustainable urban growth. These insights will not only benefit Dhanbad but also serve as a model for other growing cities facing similar challenges.

12.CONTRIBUTION TO THE EXISTING KNOWLEDGE

The research will improve knowledge of the Urban Heat Island (UHI) phenomenon in Dhanbad. This research is expected to fill gaps in UHI literature by providing a comprehensive analysis specific to a rapidly urbanizing mid-sized city. Explores the relationship between urban planning and UHI, particularly in medium-sized Indian cities. It will offer specific information about the area's temperature trends and alterations in land use, emphasizing the connections between urban development and climate shifts. The results will provide evidence-based strategies for climate adaptation and sustainable development in Dhanbad urban areas. It will offer a model for similar studies in other Indian cities, inform local policies for sustainable urban development, and improve resilience against the urban heat challenges by presenting data-driven insights and practical recommendations.

13. FUTURE WORK

- This research will help to focus on future design and planning strategies specific to Dhanbad to mitigate the Urban Heat Island effect, enhancing environmental quality and urban liveability.

- This finding work will focus on assessing Dhanbad's UHI effects through satellite data analysis, identifying temperature anomalies, and developing strategies for urban planning to enhance thermal comfort and green spaces.
- This analysis work may focus on assessing mitigation strategies, analysing long-term temperature trends, and evaluating the effectiveness of green infrastructure in reducing the Urban Heat Island effect in Dhanbad.
- It will help to reduce heat related health issues and help to planning new strategies on health programme.

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